# ASSESSING BIODIVERSITY OF PHYTOPLANKTON COMMUNITIES FROM OPTICAL REMOTE SENSING

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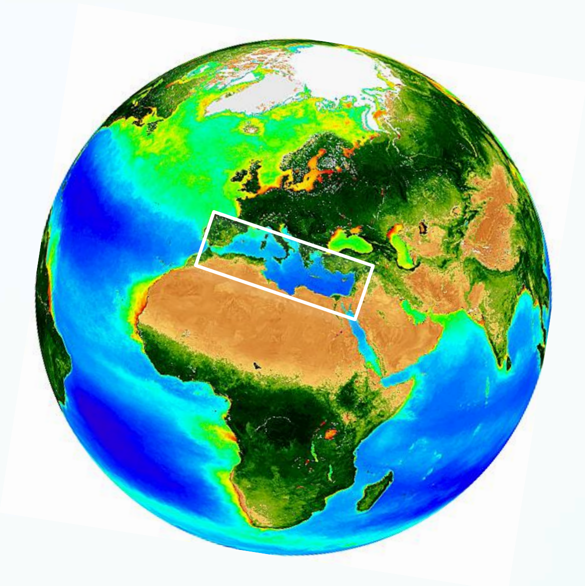
# Project objectives and strategy

Diversity of phytoplankton from optical remote sensing

1. Utilize current Chl-based approach

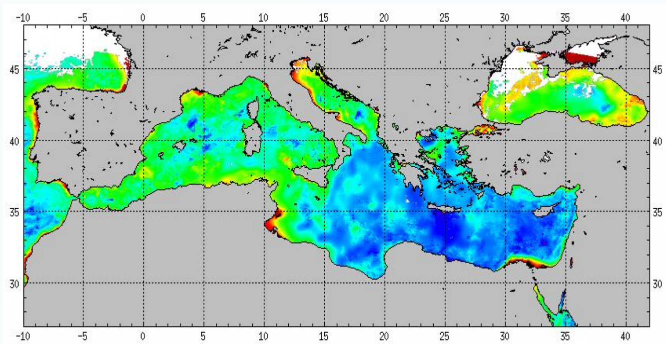
2. Explore the potential of hyperspectral approach

# Introduction



- Importance of the Mediterranean Sea
  - Considered as a small-scale model of the world ocean (Bethoux et al. 1999)
  - Identified as a "hotspot" for climate change (MerMex group 2011)
- Recent advancements in the field of remote sensing
  - New procedure for correcting ocean color-derived $Chl_{surf}$ (Morel and Gentili 2009) which is significantly overestimated by standard algorithms
  - New algorithms for discriminating phytoplankton groups from ocean color (e.g. Alvain et al. 2005; Uitz et al. 2006; Bricaud and Ciotti 2006; and many others) and estimating their contribution to total primary production (Uitz et al. 2008; 2010)
- Objective of the study
  - Combining novel approaches with 10-year SeaWiFS time series of $Chl_{surf}$
  - To reassess current estimates of total primary production
  - To propose first estimates of group-specific primary production

# Method



Monthly composite of ocean color $Chl_{surf}$

*Morel and Gentili (2009)*

Corrected $Chl_{surf}$

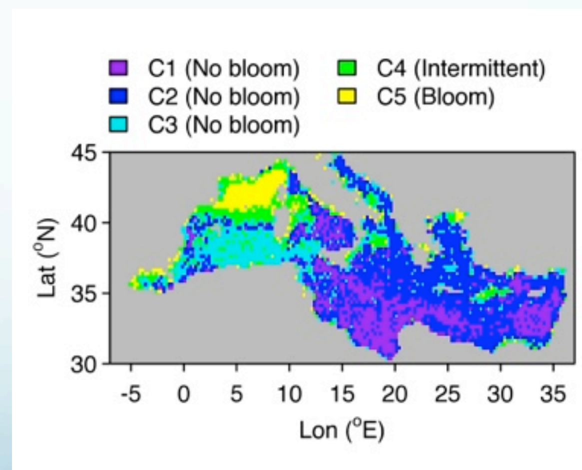
*Uitz et al. (2006)*

$Chl_{micro}$ | $Chl_{nano}$ | $Chl_{pico}$

*Morel (1991)*
*Uitz et al. (2008)*

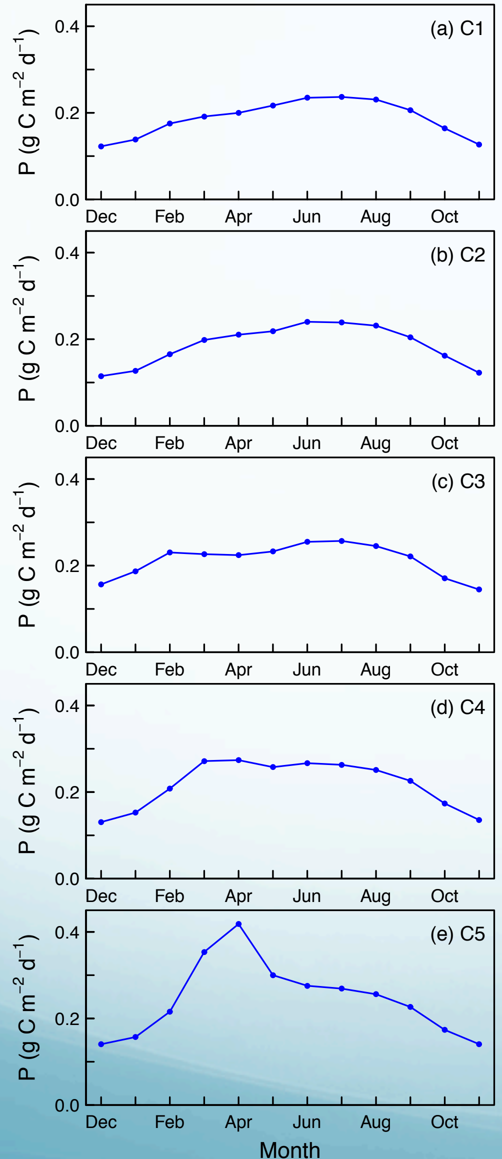
$P_{micro}$ | $P_{nano}$ | $P_{pico}$

- 3 major phytoplankton groups
  - Micro (diatoms and dinoflagellates)
  - Nano (prymnesiophytes)
  - Pico (prokaryotes and pico-eukaryotes)
- From the time series of group-specific primary production we computed
  - Annual climatology
  - Seasonal climatological cycle within 5 ecological regimes (clusters)

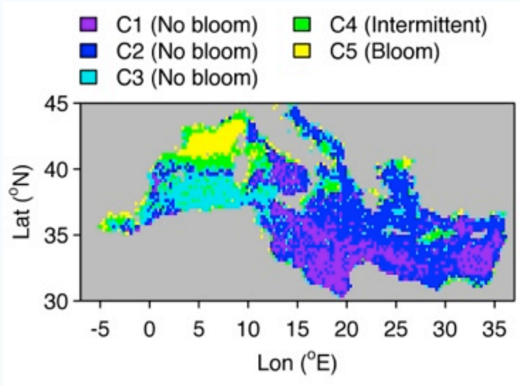



Distribution of the 5 clusters defined by D'Ortenzio and Ribera d'Alcalà (2009)

# Seasonal cycle of total primary production



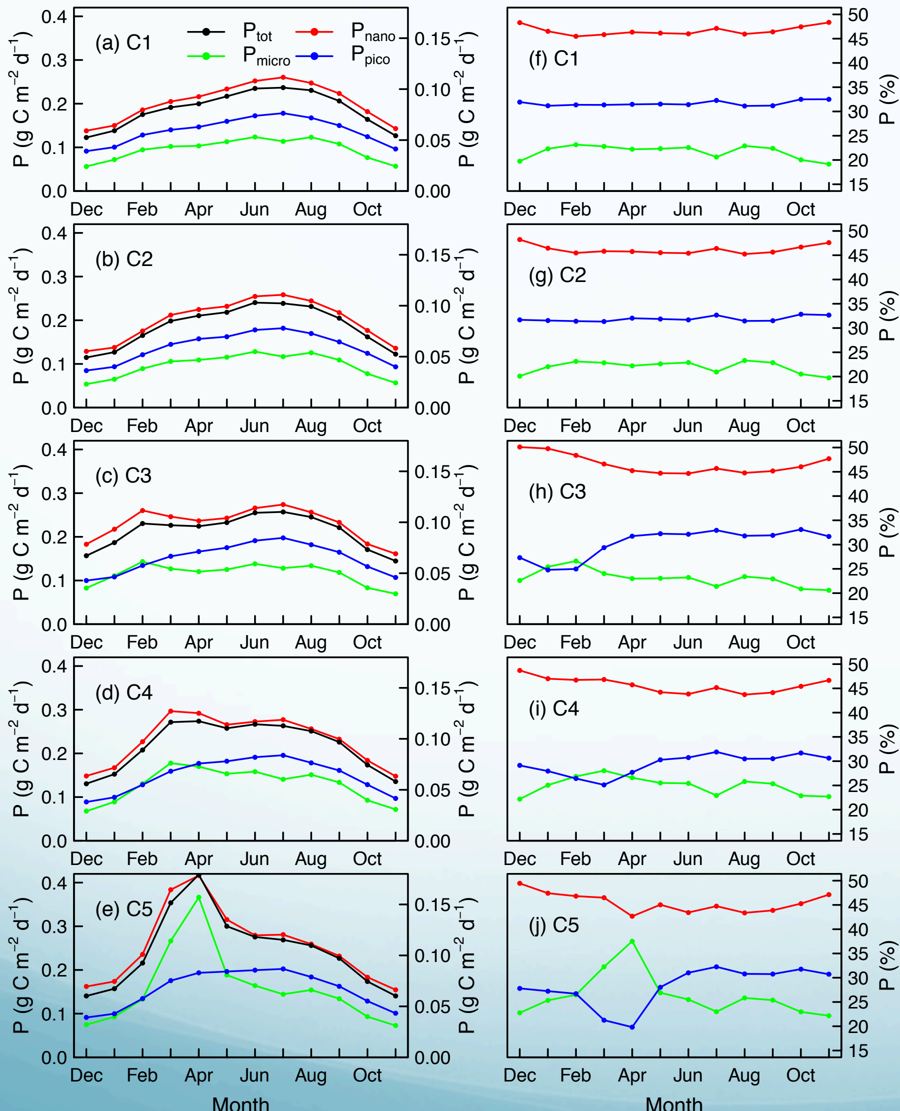

Seasonal cycle of total primary production



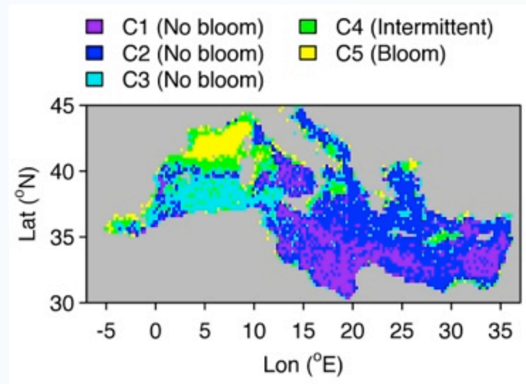

- C1-C3: Ultra-oligotrophic and oligotrophic waters
  - Lowest $P_{tot}$ rates of the entire basin
  - Maximum in June (0.24 g C m$^{-2}$ d$^{-1}$)
  - Likely results from increase in surface PAR
- C5: Ligurian Sea and Gulf of Lion
  - Prominent bloom in April (0.42 g C m$^{-2}$ d$^{-1}$)
  - Fueled by nutrient enrichment following deep winter mixing
- C4: Several confined areas of increased productivity
  - Two maxima of similar magnitude (0.27 g C m$^{-2}$ d$^{-1}$)
  - Characterized by complex physico-chemical processes

(*Uitz et al. in press GBC*)

# Seasonal cycle of group-specific primary production



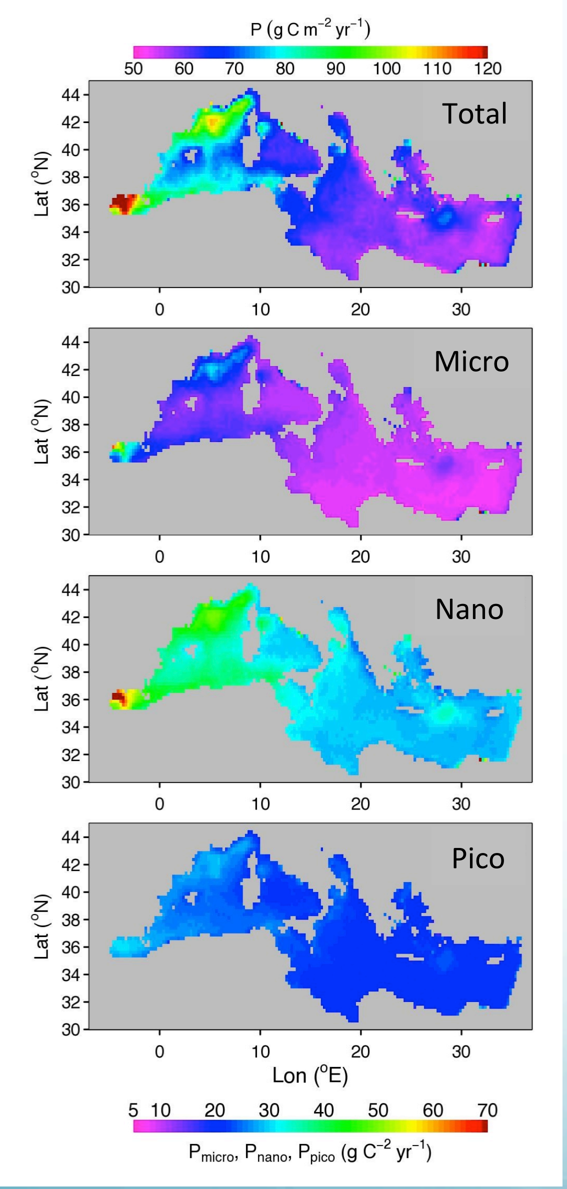

Seasonal cycle of group-specific primary production in gC m$^{-2}$ d$^{-1}$ (a-e) and % of total production (f-j)




- Seasonal cycle of $P_{nano}$ is very similar to that of $P_{tot}$
- Nano make a dominant contribution to $P_{tot}$ throughout the year in each cluster
- Relative contributions of micro and pico vary with time and ecological regime
  - Relatively stable for C1 and C2
  - More variable for C3-C5 with C5 showing the largest dynamic of the five clusters
  - Contribution of pico exceeds that of micro most of the year in the most oligotrophic conditions
  - Exception during a time period that coincides with the seasonal bloom
  - For C5 $P_{micro}$ (27-38%) is more important than $P_{pico}$ (20-27%) during a long time period of February-May

*(Uitz et al. in press GBC)*

# Conclusions

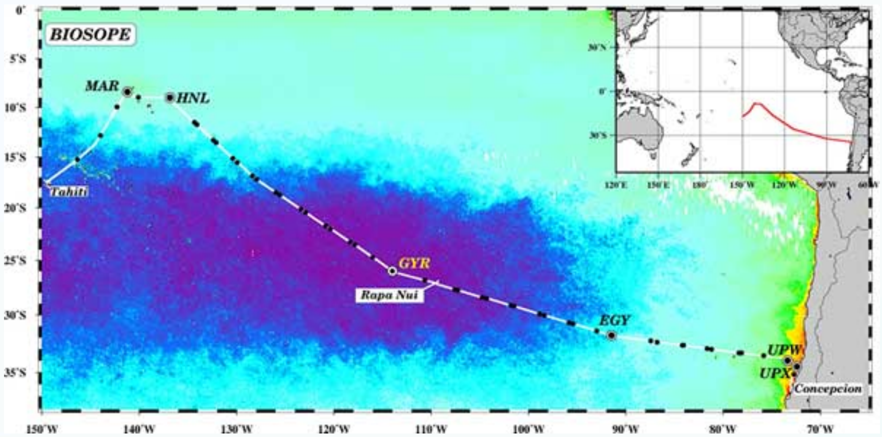



Annual (1997-2007) climatology of total and group-specific primary production

- Annual total primary production can be twice lower than previously estimated
- First climatology of phytoplankton group-specific primary production in the Mediterranean Sea
- Significant contribution to our ability to understand and quantify marine carbon cycle with implications for carbon export
- Key elements required to calibrate/validate new biogeochemical models
- Benchmark for monitoring responses of marine pelagic ecosystems to climate change

# Data

- BIOSOPE: Biogeochemistry and Optics South Pacific Experiment
- October-December 2004
- Broad range of trophic conditions
  - In the South Pacific Subtropical Gyre $Chl_{surf}$ is 0.02 mg $m^{-3}$
  - In the upwelling off Chile $Chl_{surf}$ is 3 mg $m^{-3}$
- Data
  - HPLC-determind phytoplankton pigments
  - Spectra of $a_{ph}(\lambda)$ with a 2 nm-resolution




Location of the stations during the BIOSOPE transect

| Diagnostic Pigments | Taxonomic Association |
|---|---|
| Fucoxanthin | Diatoms |
| Peridinin | Dinoflagellates |
| 19HF and 19BF | Prymnesiophytes |
| Alloxanthin | Cryptophytes |
| Chlorophylls *b* | Chlorophytes Prochlorophytes |
| Zeaxanthin | Cyanobacteria |

Utilization of the diagnostic pigments to infer phytoplankton community composition

# Method

*Input dataset*
Pigment composition

*Input dataset*
Optical measurements
(e.g. $a_{ph}(\lambda)$, $R_{rs}$ $(\lambda)$)

Derivative analysis

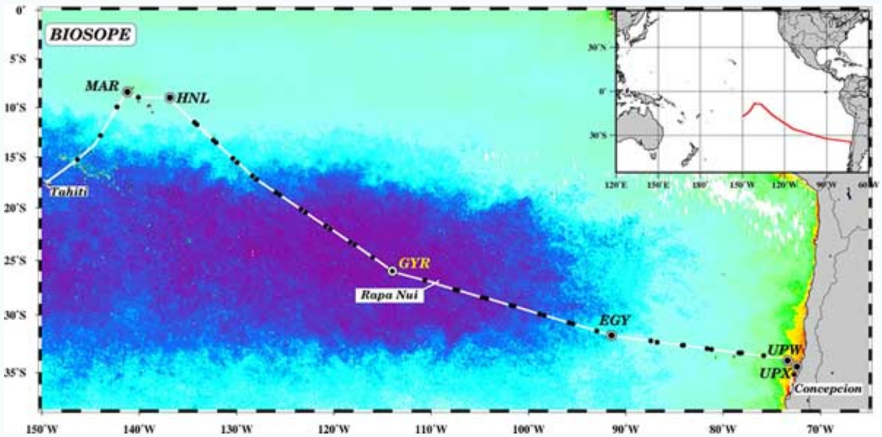
Cluster analysis
*Reference classification*

Cluster analysis

Similarity analysis
*Evaluation of performance*

(Based on *Torrecilla et al. 2011 RSE*)

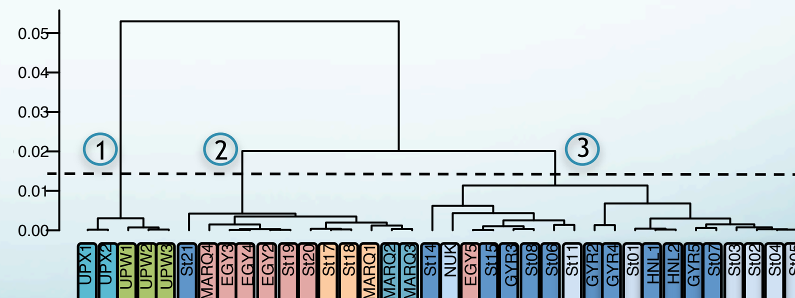
# Classification based on pigments and $a_{ph}(\lambda)$




- Cluster #1: Upwelling stations with a large contribution of diatoms
- Cluster #2: Stations nearby Marquesas Islands and EGY stations dominated by prymnesiophytes
- Cluster #3: Most oligotrophic stations dominated by pico-eukaryotes and cyanobacteria
- Only 2 stations misclassified (St21 and EGY5)

| Stations | DP |
|---|---|
| UPW1-3 | Fuco > Hex |
| UPX1-2 | TChlb > Fuco |
| St17-18, MARQ1 | Hex > Fuco |
| EGY2-5, MARQ2-4, St19-20 | Hex > Zea |
| GYR2-5, HNL1-2, St06-08, St12-15, St21 | Zea > Hex |
| St01-05, St11, NUK | Zea > DVChla |

Grouping of the stations based on the ratio of 2 dominant diagnostic pigments to Chl




Classification of the stations based on $a_{ph}(\lambda)$

# Conclusions and perspectives

- Spectra of phytoplankton absorption provide similar classification as pigment-derived phytoplankton composition
- Preliminary results indicate significant potential of hyperspectral optical approach for
  - Discriminating different marine phytoplankton assemblages
  - Monitoring phytoplankton diversity in the ocean, especially under non-bloom conditions which are the most challenging
- We are currently working to include $a_{ph}(\lambda)$ and pigment data from cruise ANT-26 onboard R/V Polarstern in the Atlantic Ocean
- Further explore the potential of the hyperspectral approach by analyzing the $R_{rs}(\lambda)$

# Project-supported publications

- Uitz J., H. Claustre, B. Gentili, and D. Stramski (2010), Phytoplankton class-specific primary production in the world's oceans: Seasonal and interannual variability from satellite observations, *Global Biogeochemical Cycles*, 24, GB3016, doi: 10.1029/2009GB003680.

- Torrecilla E., D. Stramski, R. A. Reynolds, E. Millán-Núñez, and J. Piera (2011), Cluster analysis of hyperspectral optical data for discriminating phytoplankton pigment assemblages in the open ocean, *Remote Sensing of Environment*, 115, 2578-2593.

- Uitz J., D. Stramski, B. Gentili, F. D'Ortenzio, and H. Claustre (2012), Estimates of phytoplankton class-specific and total primary production in the Mediterranean Sea from satellite ocean color observations, *Global Biogeochemical Cycles*, in press.